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**O. Tůmová / P. Netolický**

## **Computer-aided quality – Statistica and Measurement Systems Analysis**

### **ABSTRACT**

This paper deals with the problems of evaluation variability sources in a measurement system. Those variability sources are evaluated by the methods of Measurement System Analysis (MSA). The Microsoft Excel by the help of Statistica (connection through Visual Basic for Office Applications) is used for this evaluation.

### **INTRODUCTION**

When increasing quality requirements on product (particularly in automotive industry) are discussed statistical methods (are required more and more often). The effects of each variability source (known as resources management or 6M – man, machine, material, measurement, method, milieu) are evaluated on the basis of those methods. One of these sources is variability caused by measurement. This variability is quantified by uncertainty of measurement. Uncertainty of measurement deals with evaluation of gauge variability and a complete process of measurement. At present Measurement Systems Analysis (as MSA known) is also recommended (according to TS/ISO 16949 it is necessary).

The analysis by software products is a standard for today conception of statistical data analysis (in also involves analysis variability sources by the methods of Measurement System Analysis). Many of statistical products, which offer a complex support for solution of quantity statistical problems, are offered by on the software market. Each of mentioned statistical software contains mostly own operating (navigational, presentation) system of program, which is complicated not only for the control of the program itself but also for next manipulation with the results (subsumption into standard print output set, next statistical analysis of outputs etc.).

Compromise between this „lack“ and possibilities of various statistical software offers connection operating input (data, analysis type, analysis parameters) and consequently operating output (test results) to one of easier available, more expanded and more user-friendly environment,

e.g. office spreadsheet Microsoft Excel. This „new“ environment guarantee easier possibility for postprocessing the results.

In this paper we tried to connect office spreadsheet Microsoft Excel with the statistical software Statistica<sup>1</sup>. We tried to connect the environment of Microsoft Excel, which is known for many users, with the possibilities (many of statistical tools) of statistical software Statistica. This objective is implemented on the analysis of the measurement system because our Department of Technologies and Measurement deals with problems of measurement systems errors analysis (uncertainty, MSA).

## MEASUREMENT SYSTEMS ANALYSIS

The Measurement Systems Analysis is used for the estimation of measurement errors, deals with the quantification of the variabilities which can be detected in a measurement system. Evaluation of a measurement system is determined by quality of measured data, which is defined by characteristics of multiplied measuring from a system working under stable conditions.

These statistical characteristics are particularly - *expectation* as a location indicator and *variance* as a dispersion rate about expectation. From these statistical characteristics are derived typical sources of variabilities, which can be detected in a measurement system:

- *bias* – Bias is defined as the difference between the sample mean (of the measurement results) and the reference value (called as ‘true value’).
- *repeatability* - Repeatability is the variation in measurements, when one operator uses one gauge several times to measure the identical characteristic on the same part.
- *linearity* - Linearity is defined as the difference between the biases in the measuring range.
- *homogeneity* – Homogeneity is the variation (repeatability) in the measuring range.
- *stability* – Stability is the variation measured by the same measurement system on the same part or normal while measuring the one and only characteristic during a longer time period. Stability is expressed by time change of bias.
- *reproducibility* - Reproducibility is the variation in measurements, when several operators use one gauge to measure the identical characteristic on the same part.

Each source of variability above has descriptions, how to analyse the statistical significance of this source and how to determine a value of this source. The value of each source can be determined by point estimation or by confidence estimation.

The combined variability of two sources often is used according to [1]. Typical combined

variability of two sources is the variability caused by repeatability and reproducibility (methods for evaluation are called GRR, Gage R&R). For evaluation of this common variability are use the methods

- based on range (called *R*-methods) and
- based on variance (called *s*-method).

*R*-methods give fast results without deeper knowledge of mathematical statistic. It makes possible fast to determine value of *GRR* (in the case of method based on range) and separate factor of repeatability and reproducibility (in the case of method based on expectation and range). The last method based on variance needs some statistical knowledge (analysis of variance etc.), the advantage of this method is that it is able to inform about the interaction between repeatability and reproducibility too.

## **STATISTICA - STATISTICAL SOFTWARE**

Statistica is the software for statistical data analysis, involves the most of various statistical procedures. Statistica is a comprehensive, integrated data analysis, graphics, database management, and custom application development system featuring a wide selection of basic and advanced analytic procedures for business, data mining, science, and engineering applications [3]. It involves those analytic modules: Statistica Base (descriptive statistics, exploratory data analysis), Multivariate Exploratory Techniques (cluster analysis, factor analysis), Advanced Linear/Non-linear Models (analysis of variance, GLM, GRM, GLZ models), Power Analysis, Neural Networks, Quality Control Charts, Process Analysis (repeatability, reproducibility), Design of Experiments, QC Miner, Data Miner and Text Miner. This information are from [www](http://www.statsoft.com) presentation [3].

For analysis in this paper is used the Process Analysis modul.

## **EXAMPLE OF USING – SOLVING PROBLEM**

The quality characteristic of some product is the lenght. The measured data are specify as a deviation from the standard sample (which measured nominal lenght is 11,24 mm). The dimension of this lenght according to drawing is  $(11,25 \pm 2,50)$  mm.

The measurement system analysis is required for the measure of this characteristic. The requirement is to test the variability sources, which are detected in a short time. The combined variability of repeatability and reproducibility is choosen, these will be tested through the method

---

<sup>1</sup> Statistica is a product and registered mark fa Statsoft, Inc., Tulsa, Oklahoma, [www.statsoft.com](http://www.statsoft.com)

based on range (range variance estimation) and based on variance (analysis of variance)- Gage R&R methods.

Three operators, ten parts and three trial of each parts and operator are used (the experiment with two factors, one factor is an operator with three levels, second factor is a part with ten levels, number of replication is three – one plus two replication)<sup>2</sup>. The labels of operators are from 1 to 3 (no name), parts from 1 to 10 and trials from 1 to 3. The measured data are shown in the table 1.

Operator	Part	Trial	Measure
1	1	1	0,41
1	1	2	0,43
1	1	3	0,45
1	2	1	0,46
1	2	2	0,45
1	2	3	0,46
1	3	1	0,44
1	3	2	0,43
1	3	3	0,43
1	4	1	0,43
1	4	2	0,45
1	4	3	0,45
1	5	1	0,46
1	5	2	0,46
1	5	3	0,47
1	6	1	0,46
1	6	2	0,48
1	6	3	0,46
1	7	1	0,52
1	7	2	0,55

1	7	3	0,54
1	8	1	0,51
1	8	2	0,47
1	8	3	0,48
1	9	1	0,39
1	9	2	0,42
1	9	3	0,42
1	10	1	0,46
1	10	2	0,45
1	10	3	0,45
2	1	1	0,46
2	1	2	0,41
2	1	3	0,44
2	2	1	0,42
2	2	2	0,41
2	2	3	0,41
2	3	1	0,44
2	3	2	0,46
2	3	3	0,43
2	4	1	0,43
2	4	2	0,45
2	4	3	0,45
2	5	1	0,45
2	5	2	0,45

2	5	3	0,47
2	6	1	0,46
2	6	2	0,46
2	6	3	0,45
2	7	1	0,53
2	7	2	0,51
2	7	3	0,55
2	8	1	0,45
2	8	2	0,45
2	8	3	0,48
2	9	1	0,41
2	9	2	0,41
2	9	3	0,43
2	10	1	0,45
2	10	2	0,48
2	10	3	0,51
3	1	1	0,41
3	1	2	0,42
3	1	3	0,45
3	2	1	0,43
3	2	2	0,46
3	2	3	0,43
3	3	1	0,43
3	3	2	0,45

3	3	3	0,44
3	4	1	0,44
3	4	2	0,44
3	4	3	0,45
3	5	1	0,42
3	5	2	0,46
3	5	3	0,48
3	6	1	0,46
3	6	2	0,46
3	6	3	0,48
3	7	1	0,53
3	7	2	0,53
3	7	3	0,52
3	8	1	0,47
3	8	2	0,49
3	8	3	0,47
3	9	1	0,42
3	9	2	0,41
3	9	3	0,43
3	10	1	0,45
3	10	2	0,49
3	10	3	0,47

Table 1: Measured data for analysis

## METHOD FOR SOLUTION OF EXAMPLE

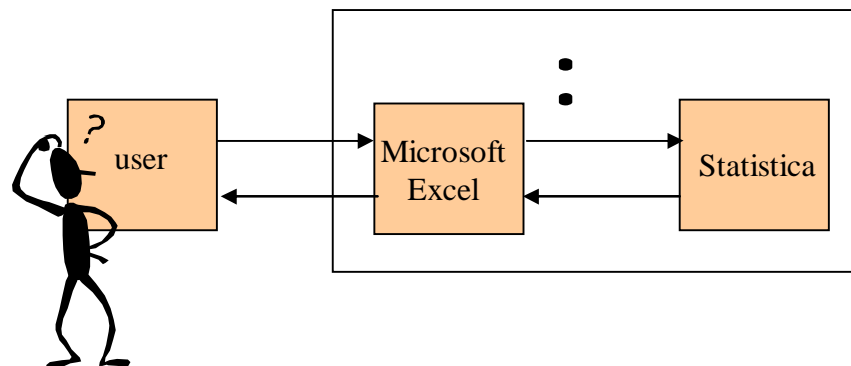
The spreadsheet program Microsoft Excel from the Microsoft Office (2000) with statistical software Statistica is used for the solution of this problem (picture 1).

The user gives input information (results of the measurement) into Microsoft Excel sheet. Then he clicks on commandbutton and the calculation is started (macro run). The program uses the Statistica libraries for results calculation. The results of calculation are transferred to the Microsoft Excel (next sheet).

The calculation with the help of software Statistica (libraries) is against background, the

<sup>2</sup> The range of variables is according to [1].

window of the statistical software is not started. The software Statistica shall be installed on computer (the libraries shall be available) and the chosen for using in the Microsoft Excel (in case of Gage R&R are the libraries STABasicStatistics and STAProcessAnalysis).



Picture 1: Using the software Statistica

The whole communication between user and computer is only through Microsoft Excel. The Visual Basic for Office Application is used for the communication between the Microsoft Excel and Statistica. The basic description for communication is described in [2].

## INPUT / OUTPUT OF EXAMPLE

The input table is shown in the picture 2. The results of both method for R & R estimation are shown in the picture 3 and 4.

	A	B	C	D	E	F	G	H
1	<b>Gage R&amp;R</b>							
2								
3	Operator	Part	Trial	Measure				
4	1	1	1	0,41				
5	1	1	2	0,43				
6	1	1	3	0,45				
7	1	2	1	0,46				
8	1	2	2	0,45				
9	1	2	3	0,46				

Picture 2: Input table

		Sigma Estimate	Variance Estimate	% R&R	% Total
Repeatability		0.015385	0.000237	100.0000	15.1999
Reproducibility		0.000000	0.000000	0.0000	0.0000
Part - to - part		0.036338	0.001320	84.8001	15.1999
Combined R & R		0.015385	0.000237	100.0000	15.1999
Total		0.039461	0.001557	100.0000	15.1999

Picture 3: Output table - method based on range (range variance estimation)

	SS	df	MS	F	p
Operators	0.000287	2	0.000143	0.44983	0.644716
Parts	0.083338	9	0.009260	29.06005	0.000000
Operators*Parts	0.005736	18	0.000319	1.30949	0.214985
Residuals	0.014600	60	0.000243	0.000000	0.000000
Total	0.103960	89	0.001168	0.000000	0.000000

Picture 4: Output table - method based on variance (analysis of variance-ANOVA)

## MACRO OF VISUAL BASIC FOR SOLUTION OF EXAMPLE

The macro which is activated by the click on commandbutton is following:

```
Sub Makrol()
'
' Gage repeatability and reproducibility
' Macro 2.6.2005, Petr Netolický
'

Application.StatusBar = "Calculation of R & R, please wait"

' define the Statistica object
Set StAp = CreateObject("Statistica.Application")
Set GageRRTable = StAp.Spreadsheets.New

Dim R As Integer: Dim C As Integer
R = 90: C = 4

'increase or decrease the size of the Spreadsheet if necessary
If (R > GageRRTable.NumberOfCases) Then
    GageRRTable.AddCases GageRRTable.NumberOfCases, _
        R - GageRRTable.NumberOfCases
ElseIf (R < GageRRTable.NumberOfCases) Then
    GageRRTable.DeleteCases R + 1, GageRRTable.NumberOfCases
End If

If (C > GageRRTable.NumberOfVariables) Then
    GageRRTable.AddVariables "New", GageRRTable.NumberOfVariables, _
        C - GageRRTable.NumberOfVariables
End If
```



```

ElseIf (C < GageRRTable.NumberOfVariables) Then
    GageRRTable.DeleteVariables C + 1, GageRRTable.NumberOfVariables
End If

' copying the data set from Excel to Statistica
For j = 1 To 4
    For i = 1 To 90
        GageRRTable.Value(i, j) = Cells(i + 3, j).Value
    Next i
Next j

' analysis by help of Statistica
Set GageRR = StAp.Analysis(scProcessAnalysis, GageRRTable)
GageRR.Dialog.TypeOfAnalysis = 3 'Selection of R & R Tests
GageRR.Run 'Next dialog

GageRR.Dialog.TypeOfAnalysis = 1
GageRR.Dialog.Variables = "1 | 2 | 3 | 4" ' Test setup - variables
GageRR.Dialog.Codes = "1 2 3 | 1 2 3 4 5 6 7 8 9 10 | 1 2 3"
GageRR.Run

With GageRR.Dialog ' Test setup - parameters of the test
    .AdjustAppraiserVariability = True
    .NoTwoWayInteraction = False
    .LevelForConfidenceInterval = 0.9
    .ToleranceForParts = 1#
    .NumberOfSigmaIntervals = 5.15
End With
' output sheet formatting
Del = False
For i = 1 To Sheets.Count
    Sheets(i).Select
    If Sheets(i).Name = "Results" Then Del = True
Next i

If Del = True Then
    Application.DisplayAlerts = False
    Sheets("Results").Delete
    Application.DisplayAlerts = True
End If
Sheets.Add(after:=Sheets("Data")).Name = "Results"

' test report
Range("A1").Select
ActiveCell.FormulaR1C1 = "Results of Gage Repeatability and Reproducibility"
With Selection.Font
    .Name = "Arial CE"
    .Size = 14
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlUnderlineStyleNone
    .ColorIndex = xlAutomatic
End With
Selection.Font.Bold = True

' copying the data set from Statistica to Excel - method based on range (Range '
Variance Estimation), for method based on variance (analysis of variance)
' replace "RangeVarianceEstimation" -> "CompleteANOVATable "
' f.e. GageRR.Dialog.CompleteANOVATable.Item(1).SelectAll
GageRR.Dialog.RangeVarianceEstimation.Item(1).SelectAll
GageRR.Dialog.RangeVarianceEstimation.Item(1).Copy
Range("B3").Select
ActiveSheet.PasteSpecial Format:="Biff4"

```

```
' formatting the output test report (font, size, table etc.)
Range("B4").Select
ActiveCell.FormulaR1C1 = "Repeatability"
...
End Sub
```

## **EXAMPLE RESULTS**

The Gage R&R is  $0,01538 / 0,03633 = 0,4233 \rightarrow 42,33\%$ , the measurement system is unsatisfactory (shown in the picture 3). No problem is with reproducibility. From picture 4 -Because the p-values parts is less than 0,05, the factor parts is statistically significant (for the significance level  $\alpha=0,05$ ). Also the problem in this case are measured parts. If we will improve this measurement system, we must concern of parts at first, because in the assembly process can be a problem.

## **CONCLUSION**

In this paper we tried to connect the environment of Microsoft Excel, which is known for many users, with the possibilities (many of statistical tools) of statistical software Statistica.

Statistica software offers (with its size) countless different statistical analysis and analysis modifications. For more complicated applications are offered own made procedures (macros). Relatively easy methods are used for access through programming language Visual Basic to statistical analysis. The cooperation with other applications (e.g. Microsoft Excel) are based just on this background (communication through Visual Basic).

The advantage of this procedure is easier using of methods for analysis (in this case Gage R&R), the disadvantage is the procedure is not universal. The modification of procedure is more difficult than by direct using of statistical software, the Visual Basic programming knowledge is required. Also this way (analysis by Microsoft Excel with the help of f.e. Statistica) can be used if the still same analysis without modification are (single purpose program).

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